USE OF LAND RESOURCE DATA TO TARGET DEGRADATION PRONE LOW CAPABILITY LANDS IN SASKATCHEWAN

A. E. Eagle[1] and G. M. Luciuk[2]

ABSTRACT

Three approaches were investigated for estimation of the extent and location of highly erodible cultivated low capability lands in Saskatchewan. The three methodologies discussed include a map overlay of generalized soils and land use data, the manipulation of a computerized soil database, and manipulation of Saskatchewan Assessment Management Agency agricultural database. Correlations have been developed that allow the targeting of such lands to the quarter section level. Total extent was variously estimated at 1.1 million acres to 7.2 million acres. The geographic distribution is concentrated (58%) in 7 Agricultural Extension Districts primarily in the southwest and west central regions, although all areas of the Province were documented to have some marginal land. The use of the data by both agricultural and non agricultural agencies in the planning of programs for conversion of lands permanent cover is discussed.

INTRODUCTION

Over the past decade numerous approximations have been made of the extent and severity of land degradation in Western Canada (Coote 1981; Bentley 1981; Goettel et al., 1981; PFRA, 1983). Some 12.8 million acres of improved land within the grain growing region of western Canada have been estimated to suffer severe topsoil loss (Anderson and Knapik, 1984). The Saskatchewan portion of this amounted to 5.5 million acres or approximately 11 percent of the improved land base. All of these degradation studies were serious attempts using the most appropriate data available. However, few, if any had access to a database that would enable an unequivocal response to the question of extent and severity (Acton, 1988).

In Saskatchewan there are lands which are at high to severe risk of soil degradation when maintained in traditional annual cultivated crop production. The risk of degradation in soil fertility, organic matter, and cropping capability occurs due to hazards such as wind and water erosion and dryland salinity. Much of this land can be managed so as to substantially reduce such erosion (Anderson, 1985; Flaten, 1986). However, portions of these lands have been observed to possess characteristics that

1 *Soil Erosion Specialist, Soil Conservation Planning Section, Soil and Water Conservation Service, Prairie Farm Rehabilitation Administration, Regina, Saskatchewan*

2 *Manager, Program Planning, Soil and Water Conservation Service, Prairie Farm Rehabilitation Administration, Regina, Saskatchewan*

either restrict their productivity or increase operating costs, thereby making them of marginal value for annual crop production under normal economic conditions (PFRA, 1987). Furthermore, these characteristics also predispose the land to severe soil degradation under annual cultivation such that improved management is inadequate to successfully conserve the soil. Such lands would correspond to Canada Land Inventory (CLI) soil capability for agriculture classes 5 and 6 and by definition have serious soil or landscape characteristics that limit their use to the production of native or tame forage crops. Accordingly, soil conservation strategies and policies for cultivated marginal lands must include possibilities for use adjustment on areas that probably should never have been developed for annual crop production. Parallel concerns in the United States have resulted in a Conservation Reserve Program (CRP) that attempts to link supply management policies, land use adjustment and soil conservation programs.

In 1987 PFRA completed a study of the possibility of a conservation reserve for marginal land conversion that would address soil degradation and land use problems in western Canada. In Saskatchewan 7.2 million acres of Canada Land Inventory class 4 to 6 lands were estimated to be under cultivation and at severe risk to wind and water erosion, or had crop yield reductions greater than 50% due to dryland salinity (PFRA, 1987). However, these initial study estimates were predicated on very generalized databases and did not permit adequate targetting of affected areas.

Three approaches were subsequently investigated and compared to refine initial estimates and to further delineate the extent and location of cultivated degradation prone marginal lands land in Saskatchewan.

METHODOLOGY

The first approach investigated employed a manual map overlay of 1:1,000,000 scale generalized soil survey, land use, and Canada Land Inventory data. The second approach manipulated the Saskatchewan soils, land use, and CLI data in the computerized Generalized Soil Landscape Map (GSLM) database using dbase 3^{+}. The third methodology utilized the Saskatchewan Assessment Management Agency agricultural quarter section data system based on developed correlations between Canada Land Inventory class ratings and Saskatchewan Assessment final productivity ratings for individual unique parcels of land.

In the first approach the 1:1,000,000 Saskatchewan Generalized Soil Landscape Map was used as a base. Soil polygons classified as having severe risk to wind or water erosion on this map were highlighted. The 1:1,000,000 scale Canada Land Inventory Map was overlayed onto this base map. Areas containing a minimum of 60% CLI class 5 and 6 land or a minimum of 40% class 5 or 6 with the remainder being CLI class 4 were delineated where such areas aligned with severe wind or water erosion risk. The next step was to identify what portion of high risk low productivity land

was cultivated. An overlay of the 1:1,000,000 Land Use map of Saskatchewan (Mack, 1982) delineated areas of predominately brush, pasture land, and cultivation. The areal extent of areas thus identified as cultivated and high risk low productivity land was done by digital planimeter.

The second approach manipulated the computerized soil attribute database associated with the soil polygons on the GSLM of Saskatchewan. The soil polygon attributes of land use (percentage cultivated), CLI percentage for dominant, subdominant and minimum CLI classes, soil polygon area, and wind and water erosion ratings were manipulated in a step-wise fashion. The records for soil polygons that had CLI class 5 or 6 designation in any of the dominant, subdominant or minimum percentage classes and rated as having severe risk to wind and water erosion were extracted from the total database. The first approximation, the upper estimate, assumed that CLI percentage designation could be proportionally applied to the area of the soil polygon under cultivation. For example, a 20,000 acre soil polygon which was 60% cultivated and had a $4T^5-5m^3-6s^2$ CLI designation was calculated as having 6,000 acres of cultivated CLI class 5 and 6 land (20,000 acres x .6 cultivation factor x .5 CLI class 5 and 6 = 6,000 acres).

The second approximation, the lower estimate, used the same data subset, but assumed that the best land would be cultivated and the poorest land uncultivated for soil polygons with less than 100% cultivation. If a soil polygon was 50% cultivated and contained 50% CLI class 1 to 4 land and 50% CLI class 5 an 6 land then it was assumed that all of the cultivation took place on the better land and none on the CLI class 5 and 6 land. Applying this assumption to our previous example, results in an estimate of 2,000 acres cultivated CLI class 5 and 6 as opposed to 6,000 acres (.6 cultivation - .5 class 1 to 4 soils x 20,000 acres = 2,000 acres).

The third approach estimated the area of cultivated CLI class 5 and 6 land based on the Saskatchewan Assessment Management Agency quarter section agricultural database. In order to use this database, a correlation between CLI classes and final productivity ratings had to be developed. A subset of 479 records distributed throughout the Province over a range of final ratings from 8 to 81 was chosen for this purpose. Initial CLI capability classes were assigned to individual soil parcels within the quarter section based on the Soil Association and textural type given by the Assessment Field Sheet and published criteria for CLI classes (Saskatchewan Institute of Pedology, 1968). Reduction of the initial CLI capability to reflect the characteristics of the specific soil parcel was further made using SIP guidelines and the profile description, "A" horizon depth, stones, topography, various physical limitations ratings such as sand, gravel, salinity, drainage and flooding among others from the assessment record. Figures 1 and 2 illustrate the soil data used from the Saskatchewan Assessment field sheet.

Figure 1
Representative Example of an Assessment Field Sheet

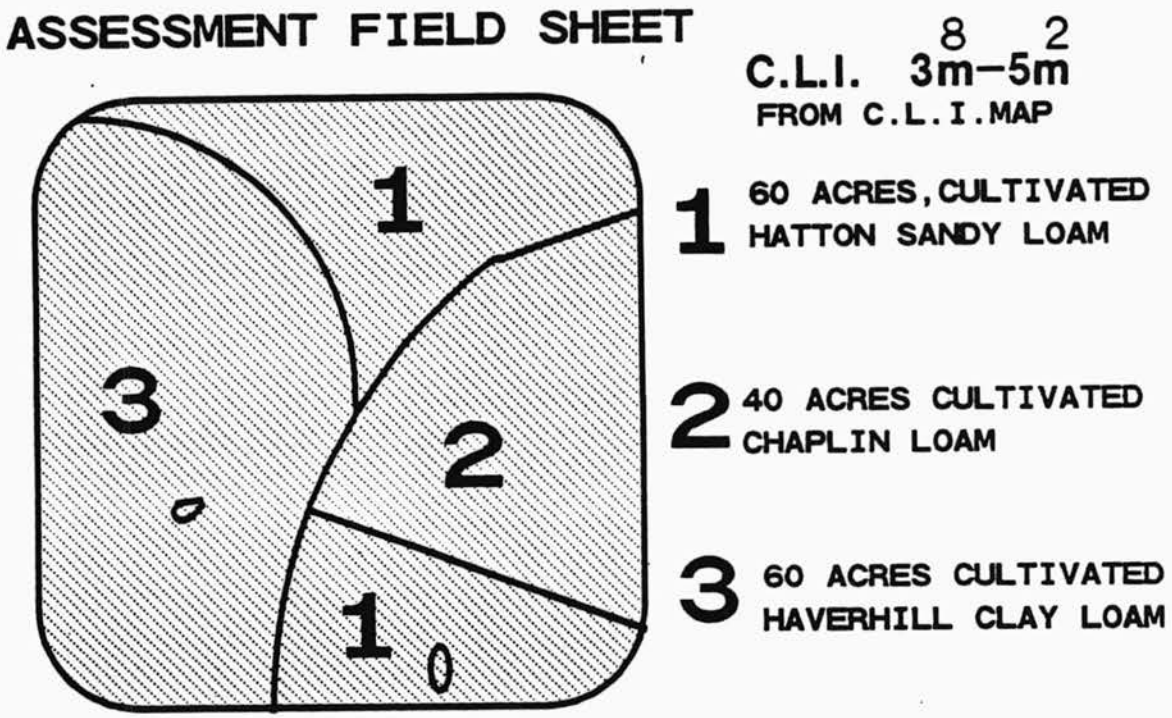


Figure 2
Representative Example of Assessement
Field Sheet Soil Data Used in the Study

LAND PARCEL	1	2	3
ACRES	60	40	60
LANDUSE	K	K-K/G	K
ASSOC.	Ht	Ch	Hr
TEXTURE	SL	GL	CL
PROFILE	OR/S	OR/S,G	OR-10
MASTER RATE	22	37	48
'A'DEPTH	2-3/85%	2-3/85%	2-3/85
PHYS. FACTORS		Sd	
PROD.RATE	19	31	41
TOPOGRAPHY	GU3	VGU	GR
STONES	0.0	S1.0	S2.5
FINAL RATE	18	29	40
C.L.I.	5m	4m	3m

Based on the correlation between CLI classes and final Assessment ratings, the entire Saskatchewan Assessment agricultural database was queried for cultivated land uses. The queries used the criteria of a minimum of 40 acres in size and final ratings less than or equal to 28. The selection of minimum acreage was arbitarily based on possible program applications of the study results at a later date.

RESULTS AND DISCUSSION

The estimates of cultivated highly erodible low capability land in Saskatchewan range from 1.1 million acres based on Saskatchewan Assessment data to 1.6 million acres based on the manual map overlay process, to 2.3-3.2 million acres based on the computerized GSLM soil database. The comparison of results is summarized in Table 1.

Table 1
Comparison of Results from the Three Methodologies

ESTIMATED ACREAGES OF CULTIVATED LOW CAPABILITY LANDS

METHOD	SCALE	ESTIMATE	REMARKS
MAP OVERLAY	1:1,000,000	1.6	CULTIVATED 5 & 6 WITH SOME 4 AT SEVERE RISK TO WIND &/OR WATER EROSION
G.S.L.M.	1:1,000,000	2.3	CULTIVATED 5 & 6 AT SEVERE RISK TO WIND &/OR WATER ASSUMES BETTER LAND IS CULTIVATED
		3.2	ASSUMES C.L.I. DESIGNATIONS PROPORTIONALLY DISTRIBUTED OVER CULTIVATED AREA
ASSESSMENT	1:20,000 APPROXIMATE	1.1	CULTIVATED 5 & 6 WITH SOME 4 BASED ON FINAL RATE <=28 & MINIMUM 40 ACRE PARCEL

Each approach provided a valid estimate of the extent and relative location of the land under discussion provided the user of the data appreciates the scale at which the data was collected

and the assumptions used to arrive at the estimate. The CLI, Land Use and GSL maps used in the map overlay have been prepared using data that was either reconnaissance in nature and/or generalized such that homogeneous polygon units rarely occur on the maps. At the 1:1,000,000 scale small areas of different class land are frequently included in larger map units. Areas occupying less than two kilometers ground distance were generally not mapped.

Registration of one map base to the other resulted in mapping errors caused by the different base map origins and use of maps several generations removed from the original base. Appreciating the errors of scale and in registration allows the extent and distribution of low capability land to be taken in context. The method allowed for a quick low cost estimate of low capability land from which rational planning and management decisions can be made on a provincial basis.

The second approach used to determine the extent of cultivated low capability land, analyzed cultivation, CLI and wind and water erosion risk contained in the computerized GSLM database. The computerized Generalized Soil Landscape database did not lead to any increases in data accuracy, but allowed for a second approximation of low capability land to be determined using land use, CLI and wind and water erosion risk classes.

The estimates ranged from 2.3 million acres (Table 2) assuming that the best CLI class land is cultivated first to 3.2 million acres (Table 3) assuming that the CLI class percentage designations were proportionally applied to the area of the soil polygon under cultivation.

Table 2
Partial Table Indicating the Types of Data Extracted From the G.S.L.M. Database and Resultant Area of Low Capability Land (Lower Estimate)

CULTIVATED C.L.I. 5 & 6 WITH SEVERE WIND OR WATER EROSION RISK *

POLGON NO.	% CULT.	AREA ACRES	CLI DOM	CLI SUB	CLI MIN	WIND RISK	WATER RISK	AREA CULT	MARGINAL CULT AREA
0005	0.6	57.5	5		5	M	S	34.5	34.5
0007	0.1	18.3	5		5	H	S	1.8	1.8
0039	0.9	40.4	3		5	S	S	36.4	4.0
0065	0.6	44.7	5	4	5	M	S	26.8	13.4

PROVINCIAL TOTAL 2.3 M.ACRES

* **ASSUMES BEST LAND IS CULTIVATED FIRST**

Table 3
Partial Table Indicating the Types of
Data Extracted From the G.S.L.M. Database and
and Resultant Area of Low Capability Land (Upper Estimate)

CULTIVATED C.L.I. 5 & 6 WITH SEVERE WIND OR WATER EROSION RISK *

POLGON NO.	% CULT.	AREA ACRES	CLI DOM	CLI SUB	CLI MIN	WIND RISK	WATER RISK	AREA CULT	MARGINAL* CULT AREA
0005	0.6	57.5	5		5	M	S	34.5	34.5
0007	0.1	18.3	5		5	H	S	1.8	1.8
0039	0.9	40.4	3		5	S	S	36.4	7.3
0065	0.6	44.7	5	4	5	M	S	26.8	18.8

PROVINCIAL TOTAL 3.2 M.ACRES

* ASSUMES C.L.I. DESIGNATION IS PROPORTIONALLY DISTRIBUTED WITHIN THE CULTIVATED AREA

This approach used the same scale of data used in the map overlay approach and thus includes many similar scale related data precision errors. The method did, however, provide confirmation of the approximation of cultivated low capability land developed from the first approach.

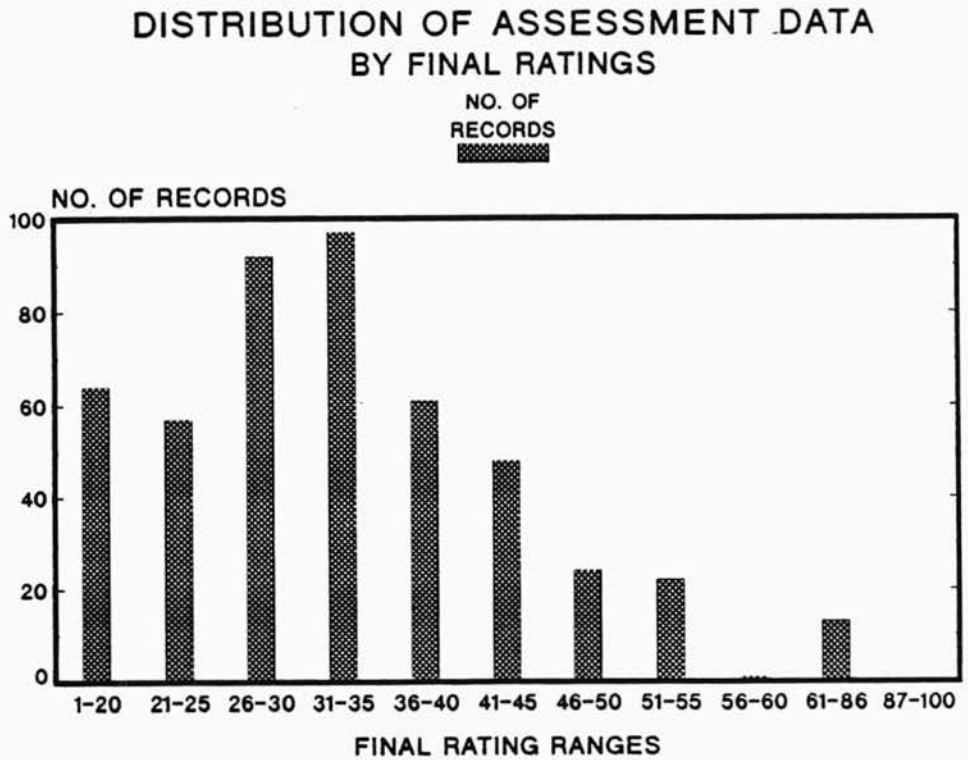
The emphasis in the first two approaches was to provide general overall estimates which could be used to make rational decisions. Attempts to employ the data on a larger scale such as for site specific decision making would lead to significant error.

The third method tested the Saskatchewan Assessment Management Agency agricultural quarter section database (1:20,000 approximate) as a source of location specific data on cultivated, low productivity land. The Saskatchewan Assessment rating system employs "Master" productivity ratings based on

characteristics that govern the soil's potential utilization and productive capacity independent of site specific physical and economic factors. This basic rating is composed of a numerical value assigned to Soil Association and is based on climate, texture and profile type. The Master rating is further adjusted by a factor based on average profile depth and local characteristics such as sand and gravel lenses, salinity, solodization, drainage, flooding and numerous others to give the Productivity Rating. This Productivity Rating is further reduced to reflect topography and stones to arrive at the Final Rating which represents the productivity of a particular parcel. In the Saskatchewan Assessment database each quarter section record is divided into unique land use/soil parcels for which a comparative final rating is provided.

To provide a common basis of comparison a correlation was necessary between the earlier databases and the Saskatchewan rating system. A sample data set of 479 land parcels was randomly selected from the total agricultural database with a prerequisite that the majority of samples had final ratings of less than 50. Figure 3 lists the distribution of Final Assessment Ratings in the 479 parcels examined. The higher proportion of records collected with lower Final ratings and

Figure 3
Distribution of the Data Records by Final Rating



with lower Final ratings was deliberate since the correlation between Final ratings and CLI 4, 5 and 6 was of primary interest. Table 4 lists the number of records and the assigned proportion by CLI class. Just over 25 percent of the records were classified as CLI class 5 and 6. The small proportion classified as CLI class 6 illustrates that the greatest proportion of cultivated low productivity land is CLI class 5.

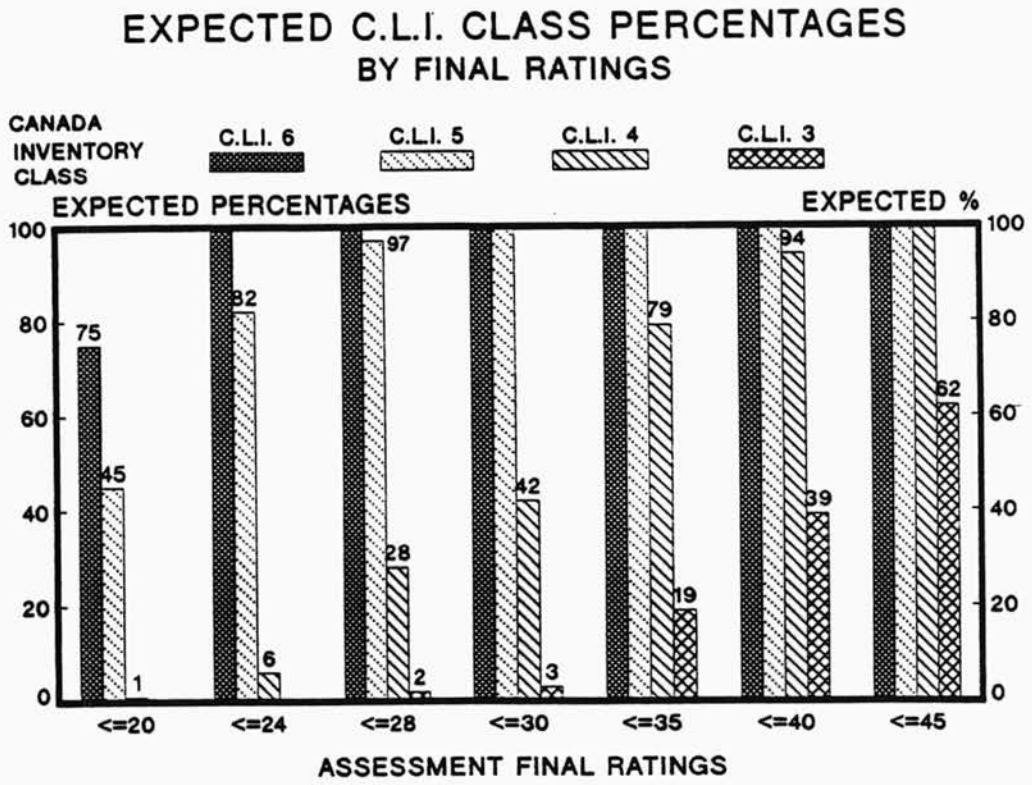
Table 4
Distribution of Records by Assigned CLI Class

DISTRIBUTION OF CALULATED C.L.I. CLASSES USING SASK. ASSESSMENT DATA

C.L.I. CLASSES	NO. OF RECORDS	PERCENT OF TOTAL SAMPLE
1	3	0.6
2	8	1.6
3	154	31.5
4	200	40.9
5	116	23.7
6	8	1.6
TOTAL	489	100

Over 80 percent of records classified as CLI class 3 had final rating greater than 35. Over 70 percent of class 4 had final ratings greater than 30. Over 97 percent of records classified as CLI class 5 had final ratings less than 28. All CLI class 6 records had final ratings less than 21. There are no distinct cutoff limits separating CLI classes. Figure 4 shows the expected proportions of CLI classes resulting from various final rating cutoffs. At a final rate of less than or equal to 28 you could expect to capture all of the cultivated CLI class 6 land, 97% of the class 5, 28% of the class 4 along with a very small (<2%) portion of the class 3 land. This was determined to be the best correlation separating the cultivated CLI class 5 and 6 by final rating.

Figure 4
Expected Proportions of CLI Class 3, 4, 5 and 6 Land at Various Final Rating Cutoffs



Subsequent to this correlation, the entire Assessment agricultural database (550,000 records) was queried for cultivated land uses to identify all parcels 40 acres in size or greater with final ratings less than or equal to 28. A subfile was created summarizing the data by RM and listing the legal location, parcel size and soil data of all parcels that met the criteria. The file contains over 13,000 parcels occupying 1.1 million acres distributed throughout Saskatchewan (Figure 5), but primarily concentrated in the southwest and west central regions of the Province. If tame hay and cultivated pasture land uses were included the area of low capability land would increase to 1.6 million acres distributed over 20,000 parcels. If a final rating of 24 was used as the cutoff a total area including cultivated pasture of 940,000 acres would result.

Over 57 percent of the cultivated land with a final rating of 28 or less is concentrated in seven Ag. Rep. districts (Table 5) and another 27 percent (Table 6) in an additional nine Ag. Rep. districts.

Figure 5
Distribution of Low Capability Land
in Saskatchewan by Rural Municipality

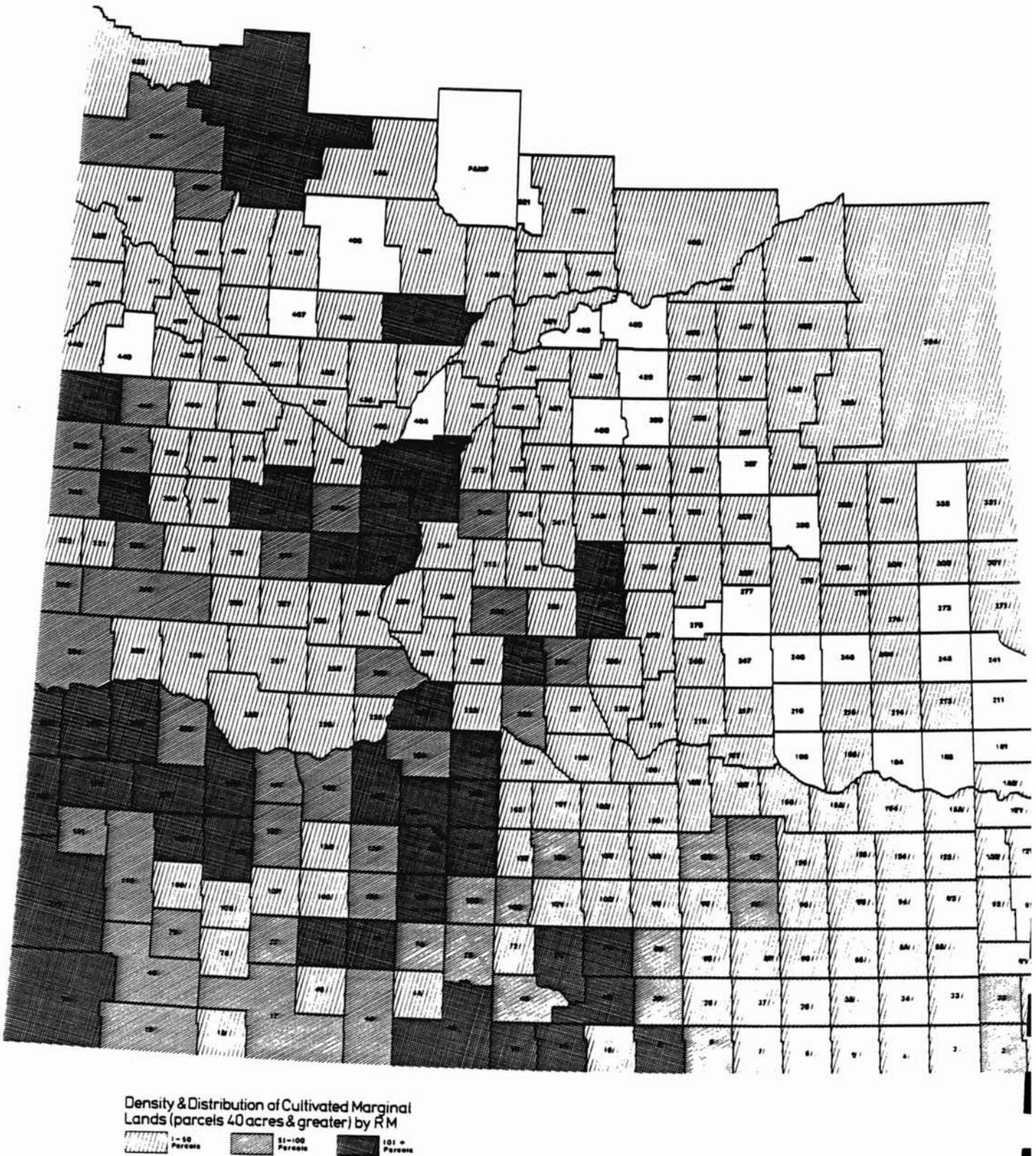


Table 5
Agricultural Districts with Greater than 50,000 acres of Cultivated Low Capability Land

SASKATCHEWAN ASSESSMENT DATA

CULTIVATED C.L.I. 5 & 6 WITH SOME 4

FINAL RATING <= 28

AGRICULTURAL DISTRICT	NO. OF PARCELS >= 40 ACRES	ACREAGE	% OF TOTAL PROV.ACREAGE
2	925	74,042	6.7
3	690	53,590	4.8
8	1003	84,055	7.6
9	903	72,858	6.6
10	1117	109,731	9.9
11	1752	165,972	14.9
23	941	79,714	7.2
	TOTAL	640,872	57.7

AGRICULTURAL DISTRICTS WITH OVER 50,000 ACRES

Table 6
Agricultural Districts with Between 20,000 and 50,000 Acres of Cultivated Low Capability Land

SASKATCHEWAN ASSESSMENT DATA

CULTIVATED C.L.I. 5 & 6 WITH SOME 4

FINAL RATING <= 28

AGRICULTURAL DISTRICT	NO. OF PARCELS >= 40 ACRES	ACREAGE	% OF TOTAL PROV.ACREAGE
4	577	46,235	4.2
7	580	41,976	3.8
15	406	32,232	2.9
16	533	37,969	3.4
22	450	33,121	3.0
24	414	30,636	2.8
30	363	26,397	2.4
36	290	21,509	1.9
43	346	27,158	2.4
	TOTAL	297,233	26.8

AGRICULTURAL DISTRICTS WITH BETWEEN 20,000 & 50,000 ACRES

USERS OF THE DATA

Several agencies have expressed interest in using the data to target low capability lands for conversion to waterfowl and wildlife habitat. The data has been used extensively within PFRA in the discussions and planning of the Permanent Cover Program. During program implementation the assessment data will prove to be invaluable in determining whether or not a specific location meets the program criteria.

Ducks Unlimited correlated their project location file with PFRA's low capability land location file which resulted in over 150 quarter sections of land where there is a common concern for land conversion.

Cultivated lands that have reverted to the Farm Credit Corporation as a result of loan default, have also been reviewed as to the proportion of marginal cultivation. Initial indications show that 10-15 percent of this land qualifies as being degradation prone low capability land.

SUMMARY

The estimate of degradation prone low capability land in Saskatchewan ranged from 1.6 to 3.2 million acres using small scale (1:1,000,000) generalized reconnaissance land use and soils data. The estimates were low cost, easily determined and provided the basis for rational provincial level planning and management decisions.

Estimates based on detailed (1:20,000) Saskatchewan Assessments agricultural quarter section database determined that 1.1 million acres of low capability land was being cultivated in Saskatchewan. The land is distributed throughout Saskatchewan comprising over 13,000 quarter sections with 57.7 percent of the total acreage occurring in seven agricultural districts (2, 3, 8, 9, 10, 11, 23) concentrated in southwest Saskatchewan. An additional 26.8 percent of the total occurs in nine Agricultural districts (4, 7, 15, 16, 22, 24, 30, 36, 43) concentrated in the south, southwest and west central regions of the province.

The use of assessment data provided site specific data necessary for the planning and implementation of land conversion programs targeting low capability land.

BIBLIOGRAPHY

Acton, D. F., 1988. National Soil Conservation Program. Internal Task Force Report.

Anderson, D. W., 1985. The effect of erosion on soil quality and productivity. pp. 26-35. In Proc. Soil Conservation "The Ultimate Challenge", Weyburn, Saskatchewan.

Anderson, M. and L. Knapik, 1984. Agricultural Land Degradation in Western Canada: A physical and economic overview. Regional Development Branch, Agriculture Canada. pp. 137.

Bentley, C. F., 1981. Agricultural land degradation summation and perspective. pp. 393-411. In Proc. of the 18th Annual Alberta Soil Science Workshop. Edmonton, Alberta.

Canada Land Inventory, Soils Capability for Agriculture. 1:1,000,000 Map Series, Saskatchewan 1976. Compiled by the Lands Directorate, Environmental Management Service, Environment Canada.

Coote, D. R., 1983. The extent of soil erosion in western canada. pp. 34-48 In "Soil Erosion and Land Degradation". Second Annual Western Provincial Conference Rationalization of Water and Soil Research and Management. Saskatoon, Saskatchewan.

Flaten, D., 1986. Soil conservation - the problem. pp. 1-6 In Proc. Soil Conservation, "A Resource Worth Saving". Swift Current, Saskatchewan.

Goettel, A. W., J. C. Hermans and D. R. Coote. 1981. Degradation by erosion. pp. 134-158 In Proc. 18th Annual Alberta Soil Science Workshop. Edmonton, Alberta.

Mack, A. R. and D. Bain, 1985. Land Use Map of Saskatchewan. 1:1,000,000 scale. Land Resource Research Centre, Research Branch, Agriculture Canada. Unpublished.

Mack, A. R., C. Prévort and D. Bain, 1986. Stratification of satellite imagery by uniform productivity areas. pp. 377-383 In Proc. 10th Canadian Symposium on Remote Sensing. Edmonton, Alberta.

Moss, H. C., 1972. A Revised Approach to Rating Saskatchewan Soils, Department of Soil Science, University of Saskatchewan. Saskatchewan Institute of Pedology, Publication M20. Saskatoon, Saskatchewan.

Prairie Farm Rehabilitation Administration, 1983. Land Degradation and Soil Conservation Issues on The Canadian Prairies, Regina, Saskatchewan. pp. 326.

Prairie Farm Rehabilitation Administration, 1987. Conservation Reserve for Marginal Land Conversion. Mimeo publication. Regina, Saskatchewan. 16 pp.

Saskatchewan Assessment Management Agency, 1979. The Saskatchewan Rural Land Assessment Manual. Regina, Saskatchewan.

Shields, J. A., H. P. W. Rostad and J. S. Clayton, 1968. A Guide to Soil Capability and Land Inventory Maps in Saskatchewan. Publication No. M8, Saskatchewan Institute of Pedology, University of Saskatchewan, Saskatoon, Saskatchewan. pp. 57.

Shields, J. A., and D. F. Acton, 1985. Generalized Soil Landscapes of Saskatchewan. Land Resource Research Centre, Research Branch, Agriculture Canada, Unpublished.